【Grant-in-Aid for Transformative Research Areas（B）】

A Study of Cellular Function and Evolution through Restorative Approach: Reconstruction of Photosynthetic Antenna Complexes (Restorative Cellular Functional Science: Reconstruction of Photosynthetic Antenna Complexes.)

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Project Information	Project Number : 24B304　Project Period (FY) : 2024-2026 Keywords : Cyanobacteria, Phycobilisome, Evolution, Nano device, Single-complex correlation observation

Purpose and Background of the Research

●Outline of the Research

Life has evolved since its birth on earth, acquiring various physiological functions to adapt to the environment, interacting with the earth in the process. How did life acquire new cellular functions? In this areas "**Restorative Cellular Functions**", we aim to understand cell functions and evolutionary principles and develop new cellular functions through the following processes (Figure 1).

Excavation: Finding diverse cellular functions from genome information in the environment in relation to the Earth's environment.

Reconstitution: reproduce these functions in the cells or in vitro to investigate their function.

Visualization: Visualize and understand the diversity of cellular functions one by one.

Beyond Nature: Based on knowledge of restored cellular function, create new cellular functions that go beyond natural functions.

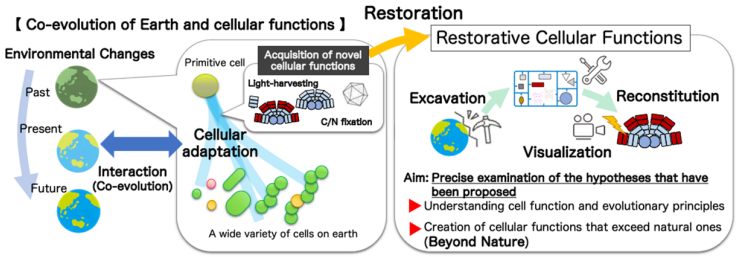

Figure 1. Overview of this research area (Restorative Cellular Functions)

One of the cellular functions of cyanobacteria is **the light-harvesting antenna complex phycobilisome**, which efficiently harvests light (Figure 2). Cyanobacteria diversify the characteristics of their phycobilisomes in response to the light environment and properly regulate energy transfer to the photosystem.

In this research area, new functions and diversity of cyanobacterial phycobilisomes will be found, and the relationship between the global light environment and the evolution of light-harvesting systems will be elucidated.

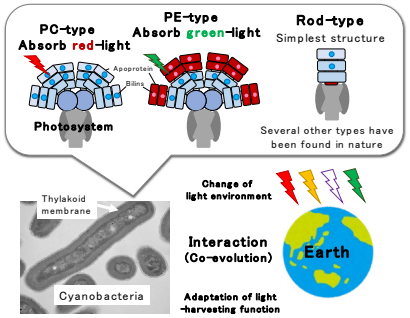

Figure 2. Light-harvesting super complex, phycobilisome

Expected Research Achievements

Linking to the diversity and changes in the Earth environment, we search for new phycobilisome genes from environmental genome information (**Excavation**), express them functionally in cyanobacterial cells, or artificial construct them *in vitro* (**Reconstitute**), and analyze the structural diversity and function of phycobilisomes at the single-molecule level using advanced microscopy techniques (**Visualization**).

This will allow us to obtain new experimental evidence regarding "co-evolution of phycobilisomes with the global light environment" and "diversity of phycobilisomes in cells". Furthermore, we will use the knowledge obtained to create a light-harvesting system that outperforms nature (**Beyond Nature**) (Figure 3).

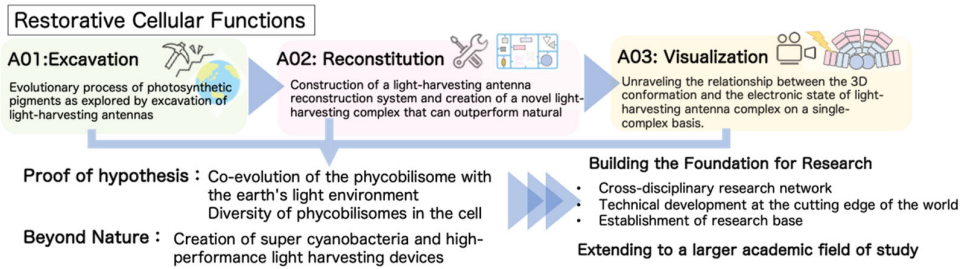

Figure 3. Research Objectives and Collaboration Organization in this Research Area

Group A01 (Taro Matsuo, Keita Miyake, Naoki Konno) :By extracting new genes related to phycobilisomes from various light environments based on environmental genome information, they will derive a correlation between the light environment of the habitat and the distribution of light-harvesting proteins and pigments.

Group A02 (Satoru Watanabe, Eiji Nakata*) : Reconstitute diverse phycobilisomes by expressing phycobilisome-associated factors in cyanobacteria. Also, artificial complexes that harvest light and transfer energy using the nanostructured "DNA oligomers" as scaffolds will be created. *Collaborating Researcher

Group A03 (Mai Watanabe, Satoru Fujiyoshi) : Cryogenic electron microscope and cryogenic fluorescence microscope will be used to obtain 3D conformation and electronic state of a single photosynthetic antenna complex (phycobilisome) , respectively. We aim to study the physiological activity of phycobilisome by correlating the data obtained from both microscopes.

●A ripple effect of this study

The research foundation of "Restorative Cellular Functional Studies," which builds on phycobilisomes as its first research subject, will provide new research concepts for various research fields and facilitate the formation of larger emerging and cross-disciplinary areas.

1. **Development of high-performance light harvesting systems:** It will be useful for the development of high-performance light-harvesting systems.
2. **Single molecule photoelectron correlation observation technique** : Microscopy techniques available for a variety of cell functions will be provided.
3. **Expansion to Earth and planetary science research** It provides a new perspective on conventional relationship between Earth and cyanobacteria and expands our results to search for life on distant planets.

Homepage Address, etc.	https://restorative-cell-func.jp/